

Final Exam
AB E 313.3 Instrumentation and
AB E 807.3 Advanced Measurements
April 13, 2002

3 hours

Answer in booklet provided unless indicated otherwise.

Closed book – no aids
Calculators permitted

- 1) Define the following, with regard to the material that has been covered in this course.
 - a) null balance system
 - b) self temperature compensation
 - c) gage factor
 - d) fixed cistern manometer
 - e) virtual short concept
- 2) Consider the resistance network, as shown in Figure 1. In this circuit, $R_1=1000\Omega$, $R_2=500\Omega$ and $R_3=250\Omega$, while $V_s=15V$. Assume that there is no error in the resistance values.

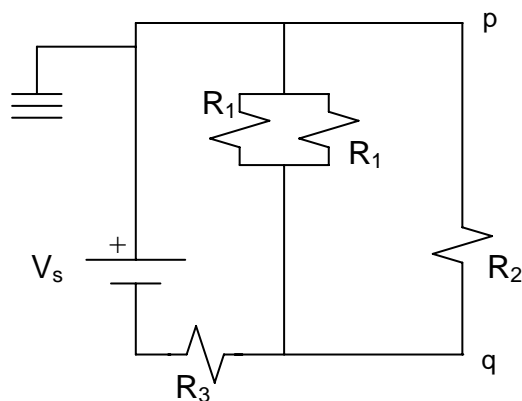
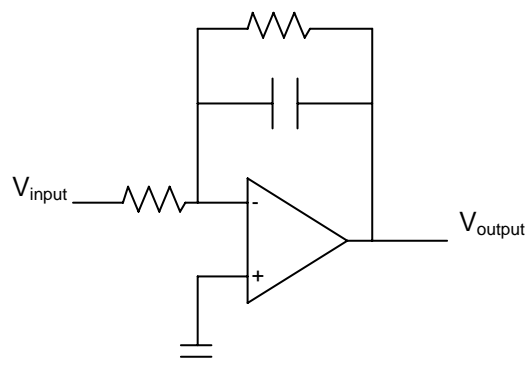
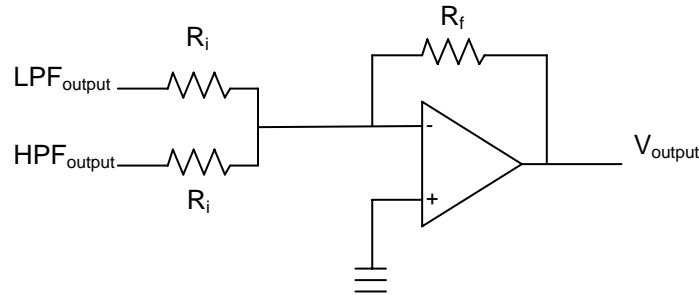


Figure 1. Resistance network.

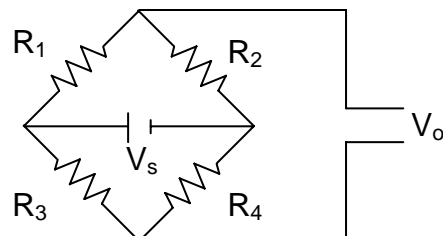
- a) Use circuit analysis to calculate the current through R_2 .
- b) You decide to measure the voltage drop across R_2 (points p and q) using an oscilloscope, to confirm your calculations. Describe (a sketch might be useful) how you would make the connections to make this measurement. What would be the indicated voltage? (assume that the oscilloscope does not load the circuit).
- c) In case b) above, what mode of triggering on the oscilloscope would you use? Explain.
- 3) Explain how a micromanometer functions
- 4) Explain the phase relationships between displacement, velocity and acceleration signals.
- 5) Show that the circuit below is a low-pass filter. If the resistor in the feedback loop has a resistance of 10000Ω and the input resistor has a resistance of 5000Ω , what is the DC gain? (show your work)



- 6) The output signals from a low-pass filter (LPF_{output}) and a high pass filter (HPF_{output}) are provided as inputs to the circuit below.



- a) Determine an expression for the output (V_{output}) as a function of the 2 inputs and resistive elements (Show your work).
- b) If the break frequency of the low-pass filter is less than the break frequency of the high-pass filter, what type of a filter will result from the circuit above?
- c) If the break frequency of the low-pass filter is greater than the break frequency of the high-pass filter, sketch the Bode magnitude plot.
- 7) A uniaxial (tension and compression) force transducer includes 4 active strain gages, each with a nominal (unstrained) resistance of $350\ \Omega$. They are situated on a member such that 2 of the strain gages experience tension and the other 2 experience compression. All gages experience the same magnitude of strain.
- a) Unfortunately, you have lost the second page of the manufacturer's specifications and don't know which of the 4 wires coming out of the load cell should be connected to the supply and which wires will supply the output signal. Explain how you could determine the orientation of the wire connections, using only a multimeter.
- b) If R_1 and R_2 experience a tensile strain and R_3 and R_4 experience a compressive strain for a given tensile load, how are the gages situated in the Wheatstone bridge?
- 8) Recall that a Wheatstone bridge consists of 4 resistors arranged as illustrated in the figure below.



Assume that all resistances are strain gages with a nominal (unstrained) resistance of $120\ \Omega$ and a gage factor of 2.150. Gages 1 and 2 are mounted on a member that is used to sense a compressive load. Gage 1 is mounted so that its longitudinal axis is parallel with the direction of loading. Gage 2 is mounted transverse to gage 1. The value of Poisson's ratio for this material is $\nu=0.3$. Gage 1 experiences a compressive strain of 3%. Note that resistors 3 and 4 are "dummy" gages, mounted on similar material, positioned in the vicinity of the load cell, affected only by variations in temperature. If the supply voltage is 10 V:

- a) what is the common mode voltage level and
- b) what is the differential mode voltage level?
- 9) A T-type thermocouple and a voltmeter are used to measure the thermal emf with the sensing junction of the thermocouple in fluid in a vessel and the reference junction at room temperature.
- a) What is the temperature of the fluid in the vessel if the room temperature is 20°C and the indicated thermal emf is $9.500\ \text{mV}$?
- b) If the room temperature is 17°C and the vessel temperature is 244°C , what will be the indicated voltage on the multimeter?

- 5
- 10) Explain the principles of operation for a linear variable differential transformer.
- 5
- 11) Briefly describe 2 ways to calibrate an accelerometer.

TYPE T

Reference Tables
N.I.S.T. Monograph 125

BLUE
+

RED
-

BROWN

Thermocouple
Grade

BLUE
+

RED
-

Extension
Grade

Copper
vs.
Copper-Nickel

MAXIMUM TEMPERATURE RANGE

Thermocouple Grade

- 328 to 662°F

- 200 to 350°C

Extension Grade

- 76 to 212°F

- 60 to 100°C

LIMITS OF ERROR

(whichever is Greater)

Standard: 1.0°C or 0.75% Above 0°C

1.0°C or 1.5% Below 0°C

Special: 0.5°C or 0.4%

COMMENTS, BARE WIRE ENVIRONMENT:

Mild Oxidizing, Reducing Vacuum or Inert;

Good Where Moisture is Present; Low

Temperature and Cryogenic Applications

TEMPERATURE IN DEGREES °C

REFERENCE JUNCTION AT 0°C

DEG C	0	1	2	3	4	5	6	7	8	9	10
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS										
-270	-6.258										
-260	-6.232	-6.236	-6.239	-6.242	-6.245	-6.248	-6.251	-6.253	-6.255	-6.256	-6.258
-250	-6.181	-6.187	-6.193	-6.198	-6.204	-6.209	-6.214	-6.219	-6.224	-6.228	-6.232
-240	-6.105	-6.114	-6.122	-6.130	-6.138	-6.146	-6.153	-6.160	-6.167	-6.174	-6.181
-230	-6.007	-6.018	-6.028	-6.039	-6.049	-6.059	-6.068	-6.078	-6.087	-6.096	-6.105
-220	-5.889	-5.901	-5.914	-5.926	-5.938	-5.950	-5.962	-5.973	-5.985	-5.996	-6.007
-210	-5.753	-5.767	-5.782	-5.795	-5.809	-5.823	-5.836	-5.850	-5.863	-5.876	-5.889
-200	-5.603	-5.619	-5.634	-5.650	-5.665	-5.680	-5.695	-5.710	-5.724	-5.739	-5.753
-190	-5.439	-5.456	-5.473	-5.489	-5.506	-5.522	-5.539	-5.555	-5.571	-5.587	-5.603
-180	-5.261	-5.279	-5.297	-5.315	-5.333	-5.351	-5.369	-5.387	-5.404	-5.421	-5.439
-170	-5.069	-5.089	-5.109	-5.128	-5.147	-5.167	-5.186	-5.205	-5.223	-5.242	-5.261
-160	-4.865	-4.886	-4.907	-4.928	-4.948	-4.969	-4.989	-5.010	-5.030	-5.050	-5.069
-150	-4.648	-4.670	-4.693	-4.715	-4.737	-4.758	-4.780	-4.801	-4.823	-4.844	-4.865
-140	-4.419	-4.442	-4.466	-4.489	-4.512	-4.535	-4.558	-4.581	-4.603	-4.626	-4.648
-130	-4.177	-4.202	-4.226	-4.251	-4.275	-4.299	-4.323	-4.347	-4.371	-4.395	-4.419
-120	-3.925	-3.949	-3.974	-4.000	-4.026	-4.051	-4.077	-4.102	-4.127	-4.152	-4.177
-110	-3.656	-3.684	-3.711	-3.737	-3.764	-3.791	-3.818	-3.844	-3.870	-3.897	-3.925
-100	-3.378	-3.407	-3.435	-3.463	-3.491	-3.519	-3.547	-3.574	-3.602	-3.629	-3.656
-90	-3.089	-3.118	-3.147	-3.177	-3.206	-3.235	-3.264	-3.293	-3.321	-3.350	-3.378
-80	-2.788	-2.818	-2.849	-2.879	-2.909	-2.939	-2.970	-2.999	-3.029	-3.059	-3.089
-70	-2.475	-2.507	-2.539	-2.570	-2.602	-2.633	-2.664	-2.695	-2.726	-2.757	-2.788
-60	-2.152	-2.185	-2.218	-2.250	-2.283	-2.315	-2.348	-2.380	-2.412	-2.444	-2.475
-50	-1.819	-1.853	-1.886	-1.920	-1.953	-1.987	-2.020	-2.053	-2.087	-2.120	-2.152
-40	-1.475	-1.510	-1.544	-1.579	-1.614	-1.648	-1.682	-1.717	-1.751	-1.785	-1.819
-30	-1.121	-1.157	-1.192	-1.228	-1.263	-1.299	-1.334	-1.370	-1.405	-1.440	-1.475
-20	-0.757	-0.794	-0.830	-0.867	-0.903	-0.940	-0.976	-1.013	-1.049	-1.085	-1.121
-10	-0.383	-0.421	-0.458	-0.496	-0.534	-0.571	-0.608	-0.646	-0.683	-0.720	-0.757
0	0.000	-0.039	-0.077	-0.116	-0.154	-0.193	-0.231	-0.269	-0.307	-0.345	-0.383
10	0.391	0.430	0.470	0.510	0.549	0.589	0.629	0.669	0.709	0.749	0.789
20	0.789	0.830	0.870	0.911	0.951	0.992	1.032	1.073	1.114	1.155	1.196
30	1.196	1.237	1.279	1.320	1.361	1.403	1.444	1.486	1.528	1.569	1.611
40	1.611	1.653	1.695	1.738	1.780	1.822	1.865	1.907	1.950	1.992	2.035
50	2.035	2.078	2.121	2.164	2.207	2.250	2.294	2.337	2.380	2.424	2.467
60	2.467	2.511	2.555	2.599	2.643	2.687	2.731	2.775	2.819	2.864	2.908
70	2.908	2.953	2.997	3.042	3.087	3.131	3.176	3.221	3.266	3.312	3.357
80	3.357	3.402	3.447	3.493	3.538	3.584	3.630	3.676	3.721	3.767	3.813
90	3.813	3.859	3.906	3.952	3.998	4.044	4.091	4.137	4.184	4.231	4.277
100	4.277	4.324	4.371	4.418	4.465	4.512	4.559	4.607	4.654	4.701	4.749
110	4.749	4.796	4.844	4.891	4.939	4.987	5.035	5.083	5.131	5.179	5.227
120	5.227	5.275	5.324	5.372	5.420	5.469	5.517	5.566	5.615	5.663	5.712
130	5.712	5.761	5.810	5.859	5.908	5.957	6.007	6.056	6.105	6.155	6.204
140	6.204	6.254	6.303	6.353	6.403	6.452	6.502	6.552	6.602	6.652	6.702
150	6.702	6.753	6.803	6.853	6.903	6.954	7.004	7.055	7.106	7.156	7.207
160	7.207	7.258	7.309	7.360	7.411	7.462	7.513	7.564	7.615	7.666	7.718
170	7.718	7.769	7.821	7.872	7.924	7.975	8.027	8.079	8.131	8.183	8.235
180	8.235	8.287	8.339	8.391	8.443	8.495	8.548	8.600	8.652	8.705	8.757
190	8.757	8.810	8.863	8.915	8.968	9.021	9.074	9.127	9.180	9.233	9.286
200	9.286	9.339	9.392	9.446	9.499	9.553	9.606	9.659	9.713	9.767	9.820
210	9.820	9.874	9.928	9.982	10.036	10.090	10.144	10.198	10.252	10.306	10.360
220	10.360	10.414	10.469	10.523	10.578	10.632	10.687	10.741	10.796	10.851	10.905
230	10.905	10.960	11.015	11.070	11.125	11.180	11.235	11.290	11.345	11.401	11.456
240	11.456	11.511	11.566	11.622	11.677	11.733	11.788	11.844	11.900	11.956	12.011
250	12.011	12.067	12.123	12.179	12.235	12.291	12.347	12.403	12.459	12.515	12.572
260	12.572	12.628	12.684	12.741	12.797	12.854	12.910	12.967	13.024	13.080	13.137
270	13.137	13.194	13.251	13.307	13.364	13.421	13.478	13.535	13.592	13.650	13.707
280	13.707	13.764	13.821	13.879	13.936	13.993	14.051	14.108	14.166	14.223	14.281
290	14.281	14.339	14.396	14.454	14.512	14.570	14.628	14.686	14.744	14.802	14.860
300	14.860	14.918	14.976	15.034	15.092	15.151	15.209	15.267	15.326	15.384	15.443
310	15.443	15.501	15.560	15.619	15.677	15.736	15.795	15.853	15.912	15.971	16.030
320	16.030	16.089	16.148	16.207	16.266	16.325	16.384	16.444	16.503	16.562	16.621
330	16.621	16.681	16.740	16.800	16.859	16.919	16.978	17.038	17.097	17.157	17.217
340	17.217	17.277	17.336	17.396	17.456	17.516	17.576	17.636	17.696	17.756	17.816
350	17.816	17.877	17.937	17.997	18.057	18.118	18.178	18.238	18.299	18.359	18.420
360	18.420	18.480	18.541	18.602	18.662	18.723	18.784	18.845	18.905	18.966	19.027
370	19.027	19.088	19.149	19.210	19.271	19.332	19.393	19.455	19.516	19.577	19.638
380	19.638	19.699	19.761	19.822	19.883	19.945	20.006	20.068	20.129	20.191	20.252
390	20.252	20.314	20.376	20.437	20.499	20.560	20.622	20.684	20.746	20.807	20.869
400	20.869										
DEG C	0	1	2	3	4	5	6	7	8	9	10